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Coral disease prevalence in Gulf of Mannar and Lakshadweep Islands

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Coral disease prevalence was higher in Coral reefs of Gulf of Mannar (GOM) (Kurusadai= 23.42% and Manoli = 15.23%) than in the Lakshadweep group (Kavaratti = 11.2% and Agatti= 9.65%). white band, white pox, white plague, pink line syndrome, pink spot, yellow band, fungal blotch, black band and necrotic patches were all observed during the survey. Pink spot disease (35.08%) was the most prevalent disease among other observed infections. Massive corals especially *Porites* Spp. was highly affected (18.2%) and followed by *Pocillopora* (6%) *Acropora* (5.3%), *Goniastrea* (3.6%), *Favia* (3.5%), *Montipora* (2.3%), *Favia* (3.5%), *Galaxea* (1.3%) and *Fungia* (0.89%). Massive corals were found more susceptible to diseases than branching corals. High levels of new mortality and disease prevalence at Kavaratti and Agatti islands suggests that the coral reefs of Lakshadweep are facing increasing pressure from a variety of stresses.

[**Key words**: Disease prevalence, coral, Gulf of Mannar, Lakshadweep, Mortality].

Introduction

Coral reefs in Gulf of Mannar (GOM) and Lakshadweep islands of India have been characterized and shown to be extremely threatened by the synergistic impacts of multiple stressors including increased sedimentation, anthropogenic activities, algal over growth as well as pressures resulting from global climate change and ocean acidification. Diseases reported in the form of lesions, blotches, bands, spots, tumor outgrowths and stunted growth are possibly resultant of infections by viruses, bacteria, protozoa and fungi, although the actual etiology of most of the diseases are yet to be determined. Prolonged persistence of these infections and synergistic activity of other stresses may result in large reduction in coral cover, changes in community structure, growth and reproduction patterns[1].

An increased research focus on coral diseases studies was evident in recent decades as frequencies of disease outbreak, geographic spread of diseases and species susceptibility to multiple scleractinian diseases have all increased[2,3,4&5]. Since the first report of coral disease[6] researchers have strived to identify the causative agents, contagious factors and mortality rate for different diseases on various coral species. The impact of coral diseases is exacerbated by bleaching events, as bleaching weakens corals and when combined with secondary stressors, leads to a succession of problems resulting in complete mortality of coral colonies[7]. Coral disease research made another leap of progression when the correlation between coral disease and increased thermal stress was confirmed. Increased thermal stress have shown an increase in virulence by reduced antibiotic resistance and increased disease susceptibility[8, 9&10].

Disease resistance in corals has been reported rarely. Bleaching pathogen *Vibrio shiloi* was found unable to infect previously susceptible corals and suggested this as a sign of recently developed coral resistance to the bacterium[11].

Detailed studies have been made of a number of coral diseases in Caribbean and pacific waters. Prominent research contributions since last decade have increased the knowledge of coral bleaching and disease in India[12, 13, 14, 15, 16, 17, 18, 19& 20]. However, studies of coral disease and its impact on coral reef mortality in this region are still limited. The majority of work concentrated on specific diseases and was limited to a very specific region. Therefore, information on disease occurrence, prevalence and impact on coral cover in the GOM and Lakshadweep reefs is still

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limited. The GOM and Lakshadweep coral system face a serious challenge from emerging diseases and baseline information on the response and variability of disease through time and within reef community is still deficient. Greater knowledge is required to allow resource managers to implement large scale management programs aimed at retaining the remaining coral cover of these islands. Present study consists disease prevalence of the coral communities of representative islands of Lakshadweep group (Kavaratti & Agatti) and the GOM (Kurusadai & Manoli) to investigate the diseases prevalence in these islands and within coral communities. Genus level observation of disease prevalence and intensity was conducted so as to inspect any generic specificity in disease occurrence.

Materials and Methods

Prevalence of coral diseases was studied among the representative islands of Lakshadweep group and the GOM (Fig.1). The condition pertained in the reef system of both the island groups were established using a series of line intercept transects (LIT) [21]. Replicate 20 m transects were set out at each island during the winter monsoon season of 2011.

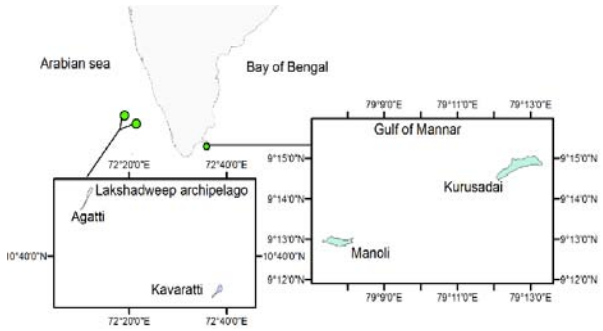


Fig.1- Study area map

All transects were laid parallel to the shore at depths of 1-5 m by snorkeling and skin diving following the reef contour. Underwater photographs were captured using a Canon power shot D series camera and corals observed from the field were identified up to the genus level with the help of Coral reef identification chart and guides[22]. Total coral cover, number of healthy, diseased and dead colonies and various disease symptoms were recorded. Sea surface temperature prevailed in the two island groups during the study period was obtained from MODIS AQUA 4km monthly averaged SST data. Necessary geometric correction was applied on the obtained satellite data and the SST pattern was characterized using band math tool in Envi 4.7.

The rate of prevalence of various diseases was recorded in percentage of prevalence[23].

$$Disease\ prevalence = \frac{Total\ number\ of\ diseased\ colonies}{Total\ number\ of\ colonies\ surveyed} \times 100$$

Disease intensity was derived as a variable of multiple diseases prevalent in coral genera through the formula:

$$Disease\ intensity = \frac{Number\ of\ diseases\ observed\ in\ a\ genus}{Total\ number\ of\ diseases\ observed\ during\ survey} \times 100$$

Coral colonies with diseases were photographed and analyzed to reveal major Disease symptoms prevailed in the coral colonies. These photographs were then compared with the underwater guide for assessment of coral health on Indo-Pacific reefs[24]. Characteristic disease symptoms observed in the field is given in Table 1 and underwater photographs of the diseases are shown in Figure 2.

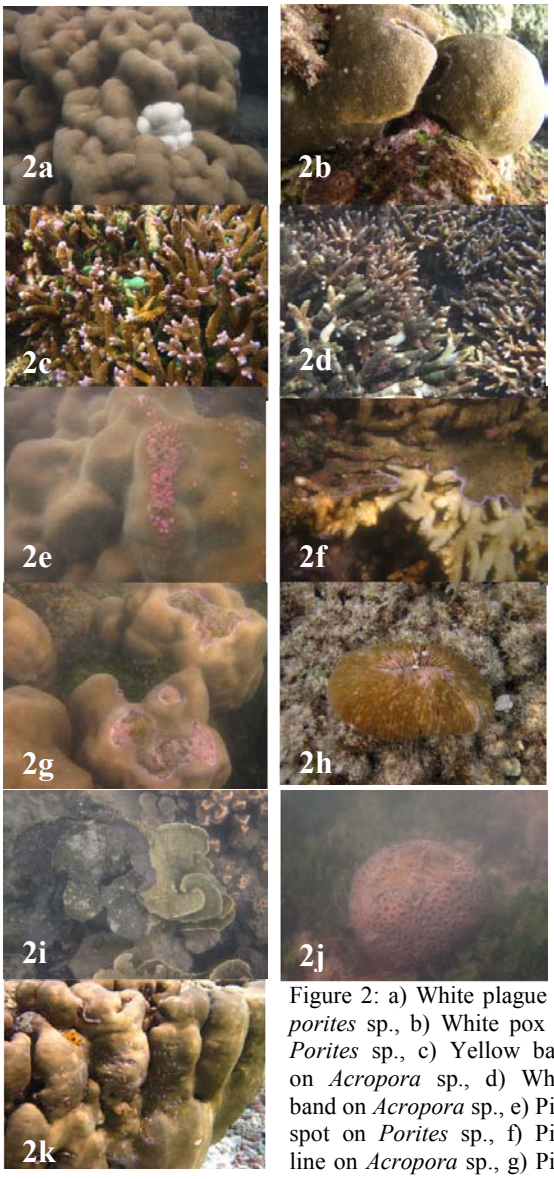


Figure 2: a) White plague on *porites* sp., b) White pox on *Porites* sp., c) Yellow band on *Acropora* sp., d) White band on *Acropora* sp., e) Pink spot on *Porites* sp., f) Pink line on *Acropora* sp., g) Pink

line on *Porites* sp., h) Pink line on *Fungia* sp., i) Necrosis on Montipora sp., j) Fungal blotch on *Favia* sp., k) Multiple stresses observed on a *Porites* colony.

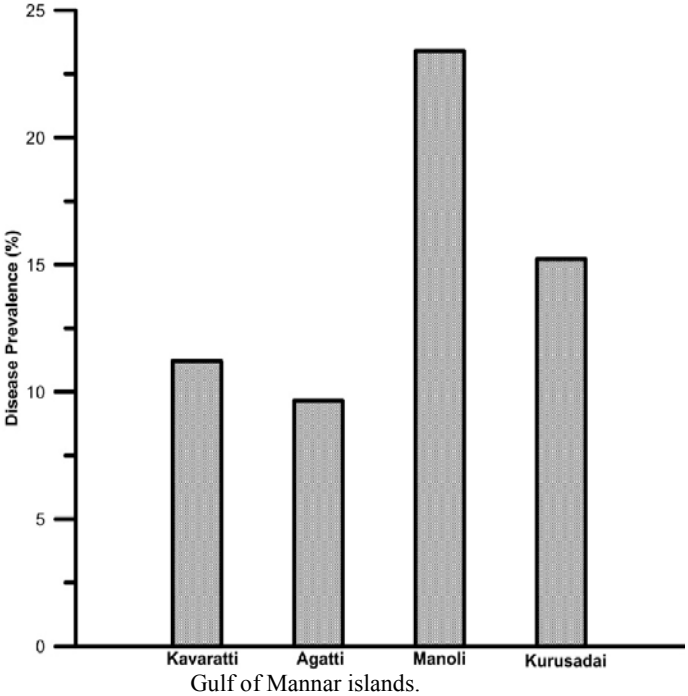
Extend of mortality of individual coral colonies at the study sites was classified by visual assessment on the basis of color, texture and algal growth. Colonies were assigned to one of three categories: recent mortality, transitional mortality and complete mortality.

Results and Discussion

Averaged disease prevalence at the GOM and Lakshadweep islands was found to be 19.35% and 10.4 % respectively (Fig. 3). Manoli island (23.42%) in GOM and Kavaratti Island (11.2%) in Lakshadweep were identified with intense coral disease spate which is tailed by Kurusadai island (GOM; 15.23%) and Agatti island (Lakshadweep; 9.65%). Variation in prevalence of coral diseases between the island groups was examined using a t-test that assumed non equal variation (based on an f-test that resulted a p value of less than alpha $0.015<0.05$). The mean disease prevalence of 10.40 ± 4.41 (n=100) in the Lakshadweep group was found significantly lower than the GOM reefs value of 19.35 ± 20.95 (n=100) and showed unequal variance ($t = -5.62$, $p \leq 8.34\times10^{-5}$). A significant variance in the prevalence of coral disease was observed between GOM and Lakshadweep islands.

SST pattern prevailed over the Indian Ocean region observed during the study period shows an increasing thermal stress in the GOM reef sites than compared to Lakshadweep group of islands (Figure 4). SST in GOM during the month of October was found ranged between 29ºC to 30ºC and a SST pattern that ranged between 28.5ºC to 30ºC was observed in Lakshadweep group of islands. This scenario of elevated SST in GOM was found prevalent through all the three months of survey. Majority of Lakshadweep region coincided with reef system was observed with an average temperature of 28.5ºC and hence formed a stress free environment for coral endurance. While, an elevated SST of 30ºC observed in GOM during the study period clearly explains possible thermal shock and allied stress over the GOM coral reefs. Situation was similar during the November and December months, that majority of the reef located regions in Lakshadweep was observed with an SST ramp of 29ºC to 29.5ºC and the GOM was recorded with 29.5ºC to 30.5ºC. Such an increased temperature and necessitated stress over the GOM reefs might have made the reefs vulnerable to a number of stressors including disease causing pathogens. The compromised host hypothesis also has suggested that coral hosts are most susceptible to diseases during periods of greater environmental stress[7]. This varying reef susceptibility to diseases from dissimilar thermal stress pattern observed in the two islands explains high disease prevalence in thermally stressed GOM than more relaxed reef system in Lakshadweep Sea where the thermal stress was nominal. Previous reports also corroborate well with the above observation that variability in progression and prevalence of disease may be explained by variability in exposure to stressors such as temperature, diving pressure, sedimentation and pollution [25].

Fig.3- Disease prevalence on coral reefs of Lakshadweep and Gulf of Mannar islands.



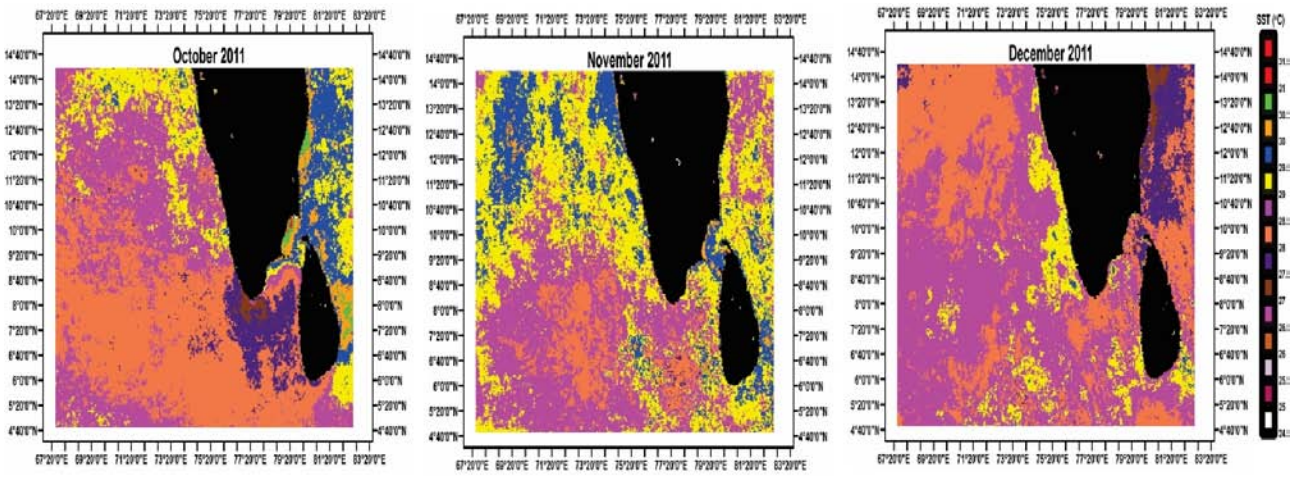


Fig.4- Sea Surface Temperature on Lakshadweep and Gulf of Mannar waters.

In addition to the environmental stressors, the disease vector population, mode of transmission of vectors and resilience of vectors to the environmental stressors all play crucial roles in determining disease prevalence. As corallivore and herbivore fish population were considered as major vectors for transmitting disease causing pathogens between different coral colonies, high corallivore and herbivore fish population observed within the GOM reef system might have promoted disease transmittance among different coral colonies.

Extend of coral mortality was determined via visual assessment on the basis of rate of tissue loss, color grade, live polyp numbers and algal invasion (Fig. 5). There were a large number of completely dead colonies in the GOM (Manoli = 34% and Kurusadai = 27%) whereas recent mortality was common in the Lakshadweep locations (Agatti = 41% and Kavaratti = 36%).

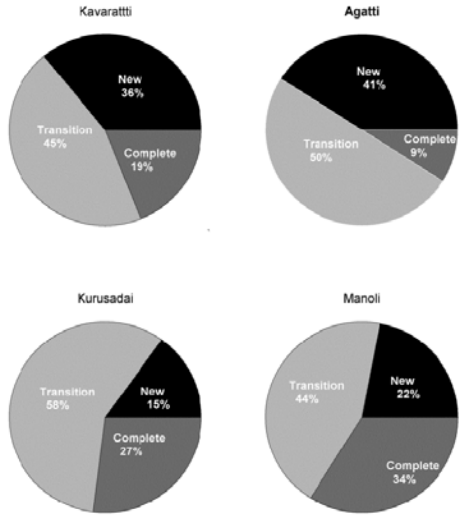


Fig.5- Coral mortality in reefs of GOM and Lakshadweep.

Increased rate of recent mortalities represents recently stressed reef ecosystem in Lakshadweep waters. Seven diseases were recorded from Kurusadai and Kavaratti islands while six coral diseases were recorded at Manoli and Agatti. Disease symptoms and incidence rate are shown in Table 1 and 2, respectively.

Disease prevalence recorded for observed coral genera at all locations are shown in Figure 6. Disease prevalence was high for *Porites* spp., with an average prevalence of 18.2%. Lower values were recorded for the genera *Pocillopora* (6%), *Acropora* (5.3%), *Goniastrea* (3.6%), *Favia* (3.5%), *Montipora* (2.3%), *Favites* (2%), *Galaxea* (1.3%) and *Fungia* (0.89%). Disease intensity is the ratio of number of disease symptoms sited in a genus to the total number of diseases sited during the survey. Disease incidence and disease intensity values for all coral genera are shown in Table 3.

Both disease prevalence and disease intensity were maximal in *Porites*, which had a disease intensity of 0.66. *Porites* was found to be affected by white plague, white pox, pink line syndrome, pink spot, black band disease and necrosis. *Acropora* showed the highest level of pink line syndrome infection at all sites and the disease intensity value was 0.5. *Pocillopora* was infected by white band and black band disease, while *Goniastrea* was infected with fungal blotch and black band disease. However with same number of infections the disease intensity for both genera was 0.22. *Favites, Favia* and *Fungia* were observed with lowest disease intensity value of 0.11.

Table 1- Symptoms of various coral diseases

Disease	Symptoms
White band	Exposure of white bare skeleton as the tissue peeled off and was sometimes occupied by macro algae.
White pox	Large or small white circular lesion and associated tissue loss
White plaque	Thick white formation in between the healthy coral region and the freshly exposed coral skeleton
Pink line syndrome	Characterized by thick or thin pink line formation over the coral surface which can extend from few millimeters to many centimeters.
Pink spot	Pink swollen polyps and associated pink coloration on surrounding polyps
Yellow band	Characterized by small to large yellow bands that can extend up to the whole colony.
Fungal blotch	Grayish brown or pale yellow colored blotch over the polyp surface.
Black band disease	Characterized by the existence of dark red or black microbial mat in between the healthy and exposed skeleton of the coral colony.
Necrosis	Occurrence of tissue sloughing

Table 2- Coral disease incidence at islands in Gulf of Mannar (GOM) and Lakshadweep group (L).

Disease	Kurusadai (GOM)	Manoli (GOM)	Kavaratti (L)	Agatti (L)
White band	+	-	+	-
White pox	+	+	+	+
White plaque	+	-	+	+
Pink line	+	+	+	+
Pink spot	+	+	+	+
Yellow band	-	+	-	-
Fungal blotch	-	+	+	-
Black band disease	+	+	+	+
Necrosis	+	-	-	+

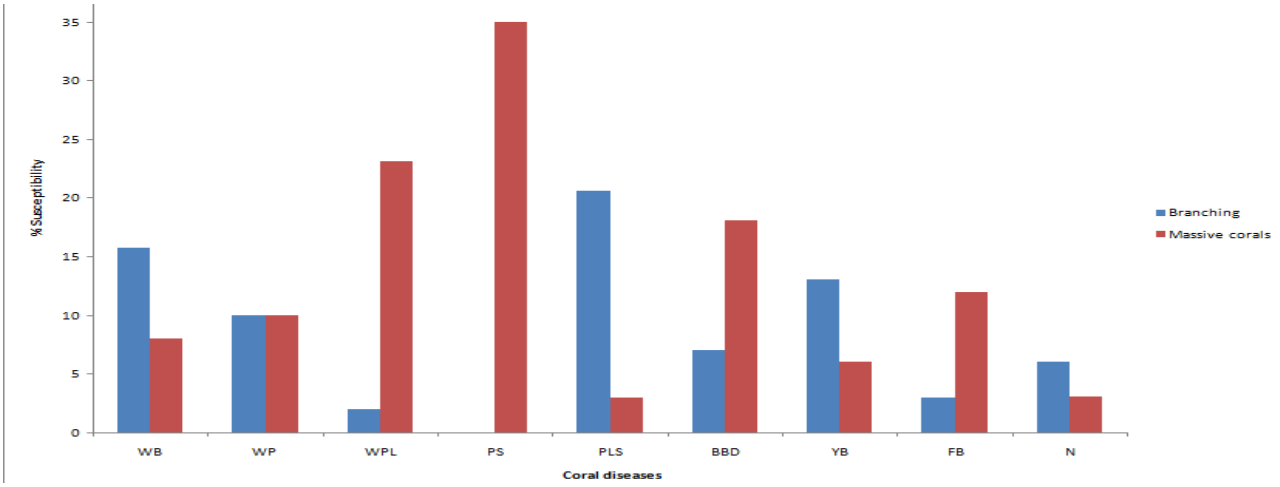


Fig. 6- Disease prevalence in corals from the Gulf of Mannar and Lakshadweep archipelago.

Table 3- Disease incidences and disease intensity recorded for various coral genera from the Gulf of Mannar and Lakshadweep archipelago.

Coral genera	White band	White pox	White plaque	Pink line syndrome	Pink spot	Yellow band	Fungal blotch	Black band disease	Necrosis	Disease intensity
Acropora	+	-	-	+	-	+	+	-	+	0.5
Montipora	-	-	-	-	-	-	-	-	+	0.1
Porites	-	+	+	+	+	-	-	+	+	0.66
Pocillopora	+	-	-	-	-	-	-	+	-	0.22
Goniastrea	-	-	-	-	-	-	+	+	-	0.22
Favites	-	-	-	-	-	-	+	-	-	0.11
Favia	-	-	-	-	-	-	+	-	-	0.11
Fungia	-	-	-	+	-	-	-	-	-	0.11

Cumulative disease prevalence among different genera varies greatly at all islands as some diseases were found to be species specific. Pink spot disease was observed only on *Porites* at all study sites, which lends support to the report of the susceptibility of this genus to this disease[26]. However, host specificity has to be confirmed from further studies for this region. The intensity and frequency of pink spot disease, which results in pink swollen polyps, is related to the presence of parasitic flat worm *Podocotyloides stenometra*[26]. Disease susceptibility in branching and massive corals is shown in Figure 7. The results indicate that massive corals are more susceptible to disease than the branched coral colonies. Similar observations were made in Puerto Rico[27] and in Hurghada corals[23].

Massive corals are more vulnerable to stress and disturbance as they have slow growth rates and the area of exposure of polyps to disease carrying pathogen and other stress factor is comparatively high in massive corals than in branching corals[28]. Present study found that massive corals were most susceptible to pink spot disease, accounting for 35.08% of the total observations, followed by white pox (23.21%) and black band disease (18.11%). In contrast, branching corals were found more vulnerable to pink line syndrome (20.6%) followed by white band (13.81), yellow band (13.05%) and white plague (10%).

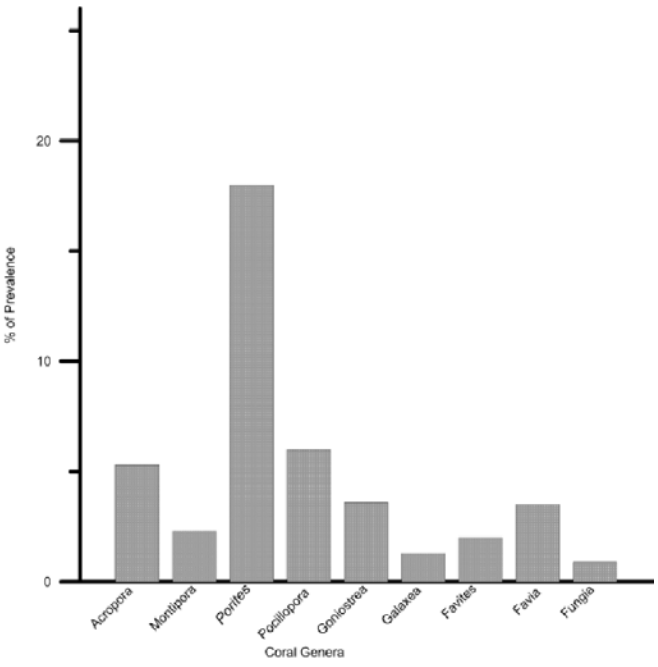


Fig.7- Disease susceptibility of branching and massive corals.

Pink spot disease, white pox, pink line syndrome and black band diseases were all widespread, occurring at all islands surveyed, while yellow

band, fungal blotch, necrosis and white band diseases were restricted to particular sites. This discrepancy may be attributed to region-specific availability of host or causative agents. We found that *Porites* was the most stressed genus in both the island groups, with highest multiple infections (Disease intensity =0.66). *Montipora* was the most disease resistant with lowest disease prevalence (1.1%) and disease intensity (Disease intensity =0.1). However, *Montipora* is highly affected by sediment associated tissue lesions. Coral disease, environmental stresses and resultant mortality are prevalent in both the island groups and further monitoring is required to determine the effects of rapid climate change and accelerated anthropogenic impacts on the coral reefs of this region.

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